Cattle grazing decreased the number of species, yet since only three morphotypes are common to both areas, total woody morphotype richness may be greatest when both ungrazed and grazed plots are maintained. Since cattle graze out their preferred species, only those morphotypes that are resistant to grazing survive. If these morphotypes are outcompeted in ungrazed areas, a management strategy permitting grazing in limited areas increases overall morphotype richness as expected by the intermediate disturbance hypothesis (Connell 1978). Thus, Palo Verde may support more species under its current controlled grazing policy than with either uncontrolled grazing or total grazer exclusion.

LITERATURE CITED

Gill, Douglas E. 1988. A Naturalist's Guide to the OTS Palo Verde Field Station, Guanacaste, Costa Rica. OTS staff.

Connell, Joseph H. 1978. Diversity in tropical rain forests and coral reefs. Science 199:1302-1309.

ZOOPLANKTON DENSITY AND DIVERSITY IN THE RÍO TEMPISQUE MARSHLAND OF PALO VERDE NATIONAL PARK

CHRIS D. CARSON, SHARON D. KARLSBERG, JOANNA M. HUBBARD, JASON H. BRADY AND AMY V. BARNHORST

Abstract. (SDK & JHB) Temperate zone freshwater bodies show distinct differences in littoral and open water zooplankton communities. We predicted an increase in zooplankton density and diversity from the open water to the littoral zone of the Río Tempisque marsh, expecting the tropical marsh to follow temperate freshwater patterns. We sampled large crustacean zooplankton in both the deeper, open water and the densely vegetated littoral zone of the marsh. We found a significantly higher density of both cladoceran and copepod zooplankton in the littoral zone. We identified a greater number of distinct mophotypes and also found a higher overall diversity of distinct large zooplankton morphotypes in the littoral zone. We attributed the higher density to increased phytoplankton abundance in the littoral zone, and the increase in both morphotype richness and diversity to structural diversity provided by emergent vegetation.

INTRODUCTION (AVB & JHB)

Diversity and density in zooplankton communities of temperate freshwater environments have been well documented (Wetzel 1983). In these ecosystems, there is a vast difference between the littoral and open water habitat. The differences in these habitats in tropical systems in terms of their diversity and density, however, have not been as well studied.

The marshland at Palo Verde National Wildlife Refuge, Guanacaste Province, Costa Rica is a seasonal marsh formed by the flooding of the Río Tempisque. Water cover over the marsh remains fairly consistent throughout the wet season, with the exception of a three month drying period (typically February-April, K. Stoner, pers. comm.). The area at the west end of the field station runway had both areas of open water lacking emergent vegetation, and areas of littoral vegetation with dense multi-species associations of emergent vegetation (*Nymphaea* spp., *Neptunia* spp., *Cyperaceae* spp.). A study of algal communities in the marsh in 1982 showed approximately 20 species of algae in the littoral zone, and no algae in the open water (Assmann 1982). This wide variety of algal habitats may have strong implications for zooplankton diversity.

We tested if the temperate zone pattern of higher zooplankton density and diversity in the littoral zone versus the open water held true in the Palo Verde tropical marsh.

METHODS (AVB & JMH)

On 9 January 1995, we sampled along two 30 m transects of the marsh at Palo Verde. One of these transects was placed in open water, defined as having no emergent vegetation within one meter of the transect, and with depth >55 cm. This transect was approximately 30m from shore. The other transect was placed in the littoral zone, defined as having emergent vegetation and a depth of <40 cm. This transect was 1.5-5 m from shore.

The open water was sampled at three different depths: 45 cm, 30 cm, 15 cm. The littoral zone was sampled at the surface, halfway to the bottom, and approximately 10 cm from the bottom (to minimize sediment in the sample). Two samples were taken at each depth with a turkey baster (yielding a sample of about 240 ml), and subsequently filtered through a 20 μm mesh screen and fixed with alcohol. A total of five samples were taken along the 30 m transect at 6m intervals. We collected four

additional samples of open water at the surface (80 ml each, across the open water transect) on 10 January 1995.

All the samples were brought up to a standard volume of 50 ml with water. One fifth of each sample was examined and morphotypes were counted and classified under a dissecting microscope. Cladocerans were distinguished only as morphotypes. Zooplankton smaller than juvenile cladocerans or copepods were not counted. Presence of rotifers was noted but not counted.

RESULTS (CDC & JMH)

We found significantly more zooplankton in the littoral zone than in the open water (Mann Whitney U-test, total large zooplankton, P=0.009, Fig. 1). Total cladocerans (P=0.012), cyclopoid copepods (P=0.011), and spiked cladocerans (the most abundant cladoceran morphotype, P=0.005) were all present in significantly greater densities in the littoral zone. One cladoceran group (referred to as "coin" cladoceran: a circular, almost two

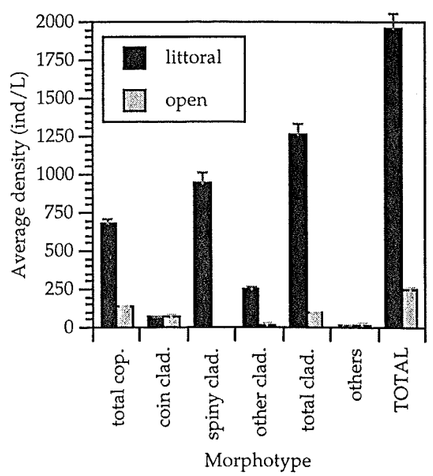

FIG. 1. Densities of zooplankton orders and two specific cladoceran morphotypes in a tropical marsh in both littoral and open water zones (mean ±SE).

dimensional species) showed no significant difference in density (P=0.91) between the open water and littoral zones. We found no zooplankton in any of the four additional open water surface samples.

We found higher morpho-species richness in the littoral zone. We identified a total of six distinct cladoceran morphotypes in the littoral zone samples, only two of which were found in the open water. Rotifers and copepods were found in both the littoral zone and the open water, and ostracods only in the littoral zone. This yielded a total of eight large crustacean morphotypes in the littoral zone and three morphotypes in the open water.

The Shannon index was used to assess proportional diversity of crustacean morphotypes in each zone, grouping non-distinctive cladocerans into a single catagory. We found that the littoral zone had a higher morphotype diversity (Shannon index = 1.201) than the open water (Shannon index = 1.106).

DISCUSSION (CDC & SDK)

Based on visual observations of plant structural variation and zooplankton food availability in the littoral zone, we expected to find a greater morphological diversity and density of large crustacean zooplankton in the littoral zone compared to the open water zone of the Río Tempisque marshland.

The large disparity in total zooplankton density between zones may be due to greater food availability or decreased mortality from predation in the littoral zone. We observed small fish in both the littoral and open waters. Predator efficiency is likely to be lower in the dense structure of vegetation that provides prey cover, thereby reducing detection and capture of zooplankton. Total phytoplankton may be lower in the open water zone due to photoinhibition of photosynthesis near the surface. Photoinhibition of photosynthesis is less likely to occur in the littoral zone where there is shading by vegetation.

Our sample size may have been insufficient to determine diversity due to

the small volume and small number of organisms sampled. Thus, our results may be only reflective of density. However, if the open water contained merely the same zooplankton population as the littoral zone in lower densities, the proportions of morphotypes in the two habitats would be approximately equal. The absence of the most abundant littoral zone group (spiny cladocerans) from the open water and the equal density of one distinct morphotype (coin cladocerans) in both environments strongly suggests that the zooplankton communities differ between the two habitats. Because visual predators are more effective in the open water, it is only the more cryptic coin cladoceran morphotype that exists in equal densities in the two habitats.

Our assessment of zooplankton diversity supports the hypothesis that the large crustacean morphotypes are both more diverse and in greater density in the littoral zone than in the open water. Both density and diversity thus seem to be influenced by structural diversity in this tropical marshland.

LITERATURE CITED

Assmann, Sally. 1982. Algal communities in the Palo Verde swamp. OTS Tropical Biology 82-3: 275-278.

Wetzel, R.L. 1983. *Limnology*. 2nd ed. Saunders: New York.